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Insecticides Resistance Spectrum in Two Field Populations of *Tuta absoluta* (Meyrick) and λ- Cyhalothrin Residues in Tomato Fruits

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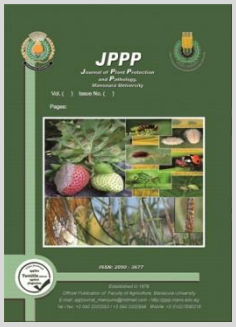

ABSTRACT

Tuta absoluta resistance to insecticides has become a dangerous problem in many tomato production areas in Egypt. We investigated the level of resistance to some insecticides currently used (λ- cyhalothrin, chlorpyrifos and imidaclopride) and recommended (chlorantraniliprole, emamectin benzoate, spinosad and indoxacarb) against *T. absoluta* which collected from two different localities, El- Salhia (Sami Saad Region, SSR) and (Abo Kabeer Region, AKR) at Sharkia governorate. Some biological aspects accompanied the tested insecticides resistance in field populations (SSR) in comparison with the laboratory reference strain (LRS) were studied. Also, the residues of λ- cyhalothrin in tomato fruits were determined. The results showed significant differences in the tolerance and/ or resistance levels to the tested insecticides among the two field populations of *T. absoluta*. The data showed that the resistance to certain insecticides namely chlorpyrifos, spinosad and lambda- cyhalothrin led to deleterious effects on some biological aspects (number of laid eggs/ female and total larval periods) in insecticides resistant field population (SSR) compared with LRS. Residues and dissipation of λ-cyhalothrin in tomato fruits were quantified at different harvest intervals of (2h), 1, 3, 5, 7, 9, 11, 13 and 15 days after insecticide application. Persistence, dissipation, half-life value and safe harvest interval of the insecticide in tomato were calculated. Results revealed that loss percentages of initial deposits in tomato fruits was 0.180 mg/ kg. and the half-life (t½) values were 1.004 day in tomato fruits. Data indicated that tomato fruits could be consumed safely after 3 days of treatment with λ-cyhalothrin.

Keywords: Insecticides resistance, *Tuta absoluta*, Biological aspects, λ- cyhalothrin residues.

INTRODUCTION

The South American tomato leafminer, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) is a serious pest of both outdoor and greenhouse tomatoes. *T. absoluta* larvae cause damage by feeding on all vegetative and fruit parts of tomato plants leading to significant yield losses of up to 100%, if the pest is not controlled (Desneux *et al*., 2010). It was originated from South America (Giordano and Silva, 1999) and was recently introduced in Europe and subsequently spread throughout the Europe and Mediterranean Basin (EPPO, 2011).

Insecticides resistance in all *T. absoluta* stages, especially larval stage is a major problem and a limiting factor for control, where it has traditionally been managed using chemical insecticides. Usually synthetic insecticides can increase yields as they reduce the damage caused by insect pests, however the high number of insecticide sprays substantially increases production costs and leads to insecticides resistance development besides eliminating its natural enemies and leading to additional occupational hazards (Siqueira *et al*., 2001). Cases of insecticides resistance in *T. absoluta* strains have been reported in Bolivia (Moore, 1983), Argentina (Lietti *et al*., 2005), Brasil (Silva *et al*., 2011) and Chile (Reyes *et al*., 2012).

Respecting studies on *T. absoluta* biology and population development are relatively few and mainly concentrated in South American countries where it is originally from these countries and the environmental conditions are favourable for the life cycle of the insect pest (Miranda *et al*., 1998). The life history of *T. absoluta* has been studied and population parameters estimated under different conditions of temperature and humidity in the laboratory environment (Erdoghan and Babaroglu, 2014; Gharekhani and Salek-Ebrahimi, 2014 and Attwa *et al*., 2015). Lambda- cyhalothrin is a nervous non- systemic insecticide. It was used extensively for *T. absoluta* control and other insect pests in tomatoes, potatoes and other crops (MacBean, 2012). So, the aim of this study was to spectrum the resistance levels to the main insecticides currently used and recommended in two field populations of *T. absoluta* at Sharkia governorate. The biological changes accompanied in SSR population comparison with LRS under the same laboratory conditions of temperature, relative humidity and photoperiods. Also, λ- cyhalothrin residues were determined in tomato fruits.

MATERIALS AND METHODS

Tuta absoluta Rearing

The laboratory reference strain of tomato leafminer, *Tuta absoluta* was parently mixed field populations collected from different infested tomato fields at Sharkia Governorate (El-Salhia) as different larval instars from collected tomato leaves samples and reared without insecticide selection for 19 generations. *T. absoluta* larvae were reared on tomato leaves. These cultivars were planted in protected cultivated area (175 m^2), Plant Protection Department, Faculty of Agriculture, Zagazig University in summer and winter seasons, respectively, irrigated and inspected every second days according to environmental conditions. Infested tomato leaves were removed and destroyed to prevent cross breeding from unknown strains. *T. absoluta* larvae of the two field populations were reared on tomato branches that cut from cultivated tomato plants for two generations under controlled laboratory conditions of 26 ± 3°C,

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70 ± 5% R.H. and 16 h L/ 8 h D. Pupae were collected from infested tomato leaflets and placed inside vials (2 diameter × 3 height cm), placed into wooden trays. After adult emergence were placed in galss lantern covered with muslin for mating and supplied with droplet of honey or sucrose solution (20%) and two intact branches of tomatoes. *T. absoluta* females that placed its eggs on all parts of tomato branches. The branches of tomato carrying eggs were placed inside plastic containers (30 diameter × 10 height cm) and changed them with other intact tomato branches daily. This process was continued until the male and female adults died. *Tuta absoluta* larvae from different developmental stages were collected from infested tomato fields from two different regions in El- Salhia (Sami Saad Region, SSR) and (Abo Kabeer Region, AKR) at Sharkia governorate and reared as above- mentioned method.

Insecticides bioassay

A leaf- dip bioassay protocol, as recommended by the Insecticide Resistance Action Committee (IRAC, 2007), was used to evaluate the susceptibility of the two different field populations and laboratory reference strain of *T. absoluta* to seven insecticides belonging to seven main groups of insecticides; synthetic pyrethroids, λ-cyhalothrin (Lambda-cyhalothrin 5% EC, El- Help manufacture), organophosphorus, chlorpyrifos (Chlorpyrifos 48% EC, El- Help manufacture), anthranilic diamides, chlorantraniliprole (Coragen 20% SC, Dupont Company), neonicotinoids, imidaclopride (Imidaclopride 24% WP, El- Help manufacture), vermectins, emamectin benzoate (Proclaim 5% SG, Syngenta), spinosyns, spinosad (Tracer 24% SC, Dwo Agrosciences Company) and oxadiazines, indoxacarb (Advantage 15% SC, Montajat Pharmaceutical Company). Tomato leaflets were collected from top third of the plant ensuring similar size and placed in a moist paper towel to avoid wilting. Commercial insecticide formulations were used in a leaf dip bioassay which is the most efficient method to evaluate the toxicity of these insecticide formulations against the fourth instar larvae (Galdino *et al*., 2011). The control leaflets were immersed in the solvent without the insecticides and other leaflets were dipped individually in the different prepared concentrations for 5s with agitation, making sure that the surfaces of the leaflets were covered with respective insecticides, allowed to air dry for 15 min. and then supplied as the sole food source to larvae. Three replicates at each of six different concentrations were used for each insecticide. Replicates consisted of a Petri dish (90 mm × 20 mm) containing a lightly moistened filter paper, one or two tomato leaflets (dependent upon size) were placed on it and inoculated with 10 larvae (4^{th} larval instars). Larvae were maintained under controlled laboratory conditions (26 ± 3°C, 60± 5% R.H. and 16h day length) and mortality was assessed after 24 h. The mortality percentages were corrected using Abbott´s formula (Abbott, 1925). The toxicity lines (Ld-P lines) were drown according to (Finney, 1971) and the LC_{50}, LC_{90} and slope values were estimated.

Biological aspects of *Tuta absoluta* laboratory reference strain and the most insecticides resistant field population

Eight pairs of both field and laboratory reference strains of *T. absoluta* adult males and females newly emerged (0-24 hours old) were determined according to the methodology proposed by Coelho and Franca (1987) were taken and put each pair in a glass lantern containing one branch of tomato and supplied with droplets of sucrose solution (20%) on its sides and tightly covered with black muslin, held in place by rubber bands and checked daily to count the number of laid eggs, then the branches of tomato carrying eggs were placed inside 50 mL glass jars and changed them with other intact tomato branches daily. This process was continued until the male and female adults died with recording eggs number as well as the dates of both initial and final eggs laid and death of male and female adults. The number of first instar larvae were counted and transferred into clean 500 mL glass jars and tightly covered with black muslin, held in place by rubber bands, checked daily and changed the tomato branches that carrying larvae with intact others until the first pupation. Then, the tomato leaves that pupae inside were checked daily and recorded the date of the first emerged adult and sexually differentiated to males and females for calculating the sex ratio of these insects that emerged from the two tested strains. These adult insects from each jar were daily collected, numbered until there are no more emergence. Then the newly male and female adults emerged (0-24 h) from the first generation of both strains were leaved to mate and female of both strains lay its eggs to calculate the mean generation period.

Field Experiment

Determinations of λ- cyhalothrin residues in tomato fruits were studied. The experiment was planted in a randomized complete block design (RCBD) with four replicates. Plot size area was 45 m^2, the distance between rows, 1.00 m, between plants distance 0.60 m. All agronomic programs were maintained constantly when required the treatment according to the plot area, calibrated and sprayed according to the schedule. This area did not receive any insecticidal treatments before the start of the experiment. A knapsack-sprayer (20 L) with one nozzle was used. Total volume of water required for four plots was calibrated. Tomato crop at the fruiting stage was spraying with λ- cyhalothrin at recommended rates (100 mL/ Fed.). Control plots were sprayed with water only. Samples were taken for all treatments from each replicate at different times of two hours, 1, 3, 5, 7, 9, 11, 13 and 15 days, of spraying. The treated fruits were collected and placed in paper bags and then transported to the laboratory for analysis. A weight of 4 kg were taken from each treatment to study the residues of the λ- cyhalothrin insecticide. Control samples were taken at the same time. The treated samples were subdivided, cutting into small pieces. All samples were stored in a freezer at−25°C until extraction.

Extraction Procedure

λ- cyhalothrin residues were extracted from tomato fruit samples with QuEChERS extraction. Tomato fruit samples were homogenized. After homogenization, a sub-sample (10 g) was taken to extract. Tomato fruit samples were put into a 50 mL falcon centrifuge tube, and 20 mL (acetonitrile) was added to the tube, and it was centrifuged for 2-3 min. Then, 2 g sodium chloride (NaCl) was added, and centrifuged for 3 min at 3000 rpm to obtain the organic layer (supernatant). 10 mL of the top organic layer was taken into 50 mL centrifuge tube to 5.5 g anhydrous sodium sulfate was added for moisture removing. 4 mL of the extract was taken into 15 mL tube containing 0.2 PSA sorbent and 0.6 g anhydrous magnesium sulphate ($MgSO_4$), and the sample tube was vortexed for 30 sec followed by centrifugation for 5 min at 3000 rpm. 2 mL of the extract was transferred into clean test tubes and centrifuged to dryness at 10 min at 4000 rpm at -5 °C and stored in the freezer until residue analysis. The extract (2 ml) was used for High-performance liquid chromatography (HPLC) analysis. λ–

cyhalothrin residues were analyzed with HPLC using a UV-detector set at the wavelength 266 nm. A reversed-phase VP-ODS C18 column (250 × 4.6 mm i.d., particle size 5 mm) was used and the mobile phase was acetonitrile/water (80/20, v/v) at 1.00 ml min^{-1}. These conditions resulted in good separations and high sensitivity at the retention time 9.6 min.

λ–cyhalothrin recovery tests were determined using untreated tomato fruits. 0.5 mg/ kg of technical λ- cyhalothrin (96% purity) was prepared and spiked on three tomato fruit samples. All the aforementioned steps of extraction and clean-up were performed. The obtained recovery percentages were 91.50.

Kinetic study

The degradation rate and half-life period of λ–cyhalothrin were calculated according to Hoskins (1961). Accordingly, the degradation rate (K) of λ–cyhalothrin and the half-life period (t½) of the tested insecticide in fruits and leaves were calculated as follows: rate of degradation K = 2.303 × slope, the half-life period can be obtained from the following equation: t½ =0.693/K.

Statistical Analysis

Mortality data were subjected to probit regression analysis using a Probit polo pc plus software v 3.1 (LeOra Software Inc., Cary, NC) which automatically corrected for control mortality according to the method of Finney (1971) and the median lethal concentrations (LC_{50}) and 90% (LC_{90}) mortalities were calculated. All data of biological parameters were subjected to analysis of (Independent- Samples T- test) using the SPSS 14.00 software (SPSS Inc. Chicago, Il, USA).

RESULTS AND DISCUSSION

Insecticides Bioassay

The relative susceptibility of *T. absoluta* larvae of the two collected populations from El- Salhia (Sami Saad Region, SSR) and Abo Kabeer (AKR) to the tested insecticides against the 4th instar larvae were assessed. It appears clearly that the indoxacarb was the superior followed by the spinosad, emamectin benzoate, chorantraniliprole, λ-cyhalothrin, imidaclopride and chlorpyrifos against the 4th instar larvae of *T. absoluta* that collected from El- Salhia locality in comparison with the laboratory reference strain. The LC_{50} values of indoxacarb that resulted from bioassay carried out against the 4th instar larvae of El- Salhia population and laboratory reference strain were (0.85 and 0.46, respectively µg/mL), spinosad (0.92 and 0.04 µg/mL), emamectin benzoate (1.73 and 0.32 µg/mL), chlorantraniliprole (29.48 and 19.63 µg/mL), λ-cyhalothrin (1003.78 and 91.73 µg/mL), imidaclopride (1319.16 and 363.05 µg/mL) and chorpyrifos (3108.62 and 34.12 µg/mL). Also, in Abo Kabeer population, it was found that almostly the same trend where that indoxacarb was the most toxicity followed by emamectin benzoate, spinosad, chlorantraniliprole, λ-cyhalothrin, chlorpyrifos and imidaclopride, respectively. The corresponding figures of indoxacarb, emmamectin benzoate, spinosad, chlorantraniliprole, lambda-cyhalothrin, chlorpyrifos and imidaclopride were 0.15 & 0.46 µg/mL; 0.18 & 0.32 µg/mL; 0.25 & 0.04 µg/mL; 3.97 & 19.63 µg/mL; 173.17 & 91.73 µg/mL; 282.82 & 34.12 µg/mL & 492.96 and 363.05 µg/mL for the same locality and laboratory reference strain, respectively (Table 1).

Table 1. Toxicity data of seven insecticides tested in laboratory against the fourth instar larvae of *T. absoluta* El-Salhia and Abo Kabeer populations comparing with a laboratory strain under laboratory conditions of 26°C and 65% R.H.

Insecticide	Collected Population	LC_{50} (µg/ml)	Confidence Limits		LC_{90} (µg/ml)	Confidence Limits		Slope	Relative tolerance*	
			Lower	Upper		Lower	Upper		LC_{50}	LC_{90}
λ-cyhalothrin	El- Salhia	1003.78	455.85	14897.4	28688.6	4072.53	493208.8	2.36	10.94	9.79
	Abo Kabeer	173.17	137.83	210.52	423.98	329.03	652.49	2.38	1.89	0.14
	Lab. Strain	91.73	7.64	1101.13	2930.8	7.26	11838.8	3.33		
Chlorpyrifos	El- Salhia	3108.62	452.93	21335.67	22831.58	378.13	1378577.3	1.48	91.11	139.23
	Abo Kabeer	282.82	99.51	567.31	699.35	405.99	24266.21	2.99	8.29	4.26
	Lab. Strain	34.12	20.23	49.99	163.99	110.56	288.09	2.12		
Chlorantraniliprole	El- Salhia	29.48	10.02	4053.8	188.78	39.80	6395.11	2.66	1.50	2.73
	Abo Kabeer	3.97	2.34	5.37	7.79	0.15	1206.51	2.37	0.20	0.11
	Lab. Strain	19.63	0.30	1272.92	69.03	0.005	1036.25	4.53		
Imidaclopride	El- Salhia	1319.16	178.28	9761.03	12736.86	92.52	1753371.9	0.94	3.63	5.05
	Abo Kabeer	492.96	406.43	573.17	1020.60	838.75	14398.4	2.94	1.36	0.40
	Lab. Strain	363.05	214.44	530.29	2521.06	1361.69	11653.59	1.10		
Emmamectin benzoate	El- Salhia	1.73	0.75	3.94	124.07	35.22	1273.81	4.83	5.41	41.08
	Abo Kabeer	0.18	0.12	0.26	0.81	0.51	1.67	6.46	0.56	0.007
	Lab. Strain	0.32	0.21	1.50	3.02	1.59	8.51	5.65		
Spinosad	El- Salhia	0.92	0.64	2.30	3.45	2.34	5.74	5.08	23.00	10.78
	Abo Kabeer	0.25	0.15	0.42	2.33	1.15	7.65	5.80	6.25	7.28
	Lab. Strain	0.04	0.002	1.18	0.32	0.02	4.56	7.02		
Indoxacarb	El- Salhia	0.85	0.41	1.51	14.61	7.33	41.52	5.08	1.85	0.76
	Abo Kabeer	0.15	0.09	0.24	1.08	0.61	2.64	6.23	0.33	0.06
	Lab. Strain	0.46	0.001	1.65	19.14	3.23	33.22	5.08		

*** Tolerance values were calculated at LC_{50} and LC_{90} levels by dividing LC_{50} and LC_{90} of field populations by LC_{50} and LC_{90} of a laboratory strain.**

According to the tolerance levels values in the two different collected populations to the seven different tested compounds, it seems clearly that all populations exhibited different degrees of resistance to these compounds comparing with the laboratory reference strain. SSR population showed the highest degree of resistance at LC_{50} levels towards chlorpyrifos, spinosad and λ-cyhalothrin (91.11, 23.00 and 10.94 fold, respectively). While, at LC_{90} levels, it was found that SSR population was the highest degree of resistance towards chlorpyrifos, emamectin benzoate and spinosad (139.23, 41.08 and 10.78 fold, respectively) compared with the laboratory reference strain. Similarly, AKR population exhibited the highest degree of tolerance at LC_{50} level to chlorpyrifos, spinosad and λ-cyhalothrin (8.29, 6.25 and 1.89 fold, respectively) compared with the laboratory reference strain. In regard to the degree of tolerance at LC_{90} level in AKR population, the results showed that the highest degree of tolerance was towards spinosad and chlorpyrifos (7.28 and 4.26

fold, respectively) in comparison with the laboratory reference strain (Table 1).

All the collected populations exhibited a high degrees of susceptibility to chlorantraniliprole and indoxacarb; AKR population recorded the highest susceptibility level (0.20 and 0.33 fold, respectively), while in case of SSR population, it was found almostly the same trend (1.50 and 1.85 fold, respectively) (Table 1).

The highest level of *T. absoluta* larvae susceptibility collected from Abo Kabeer region (AKR) to all the tested insecticides, especially indoxacarb and chlorantraniliprole may be due to the less number of insecticide sprays in this region because it has a limited areas of cultivated tomato crops compared with El- Salhia region at Sharkia governorate and both insecticides belonging to relatively novel class of insecticides. The comparison with the laboratory reference strain and especially SSR population for each insecticide indicated the existence of a possible resistance to λ-cyhalothrin, tolerance to emamectin benzoate, imidaclopride, indoxacarb and chlorantraniliprole and more interestingly a possible resistance to chlorpyrifos and spinosad.

In order to spectrum the resistance levels to the main insecticides currently field used and recommended in populations of *T. absoluta* at Sharkia governorate, Egypt. Different bioassay methods were used in the past to achieve this aim by different authors. Salazar and Araya (1997) used a direct spray based method to compare the susceptibility of collected larvae of *T. absoluta* from Chile to several commonly used insecticides applied on 3rd and 4th instar of *T. absoluta* larvae. Siqueira *et al*. (2000b) bioassayed an insecticide using impregnated filter paper to study the resistance and synergism to cartap in *T. absoluta* populations, while Alvaro *et al.* (2001), in Brazil, used the same method to evaluate the susceptibility of the same insect pest to four different insecticides. More recently, insecticide resistance action committee (IRAC) adopted and recommended, the leaf dip method for insecticides resistance studies in *T. absoluta*. Gerson *et al*. (2011), in Brazil, used the same method to survey some insecticides resistance levels in *T. absoluta* populations. Castelo Branco *et al.* (2001) used also the leaf dip method to evaluate the efficacy of the recommended field rates of some insecticides under laboratory bioassays on two Brazilian tomato pinworm populations and one diamondback moth population. Roditakis *et al*. (2013) used the leaf dip bioassay method to monitor the susceptibility of two *T. absoluta* populations collected from Greece to seven different insecticides. In our study, we used the same method to evaluate the susceptibility of two populations of the tested insect pest collected from two different localities at Sharkia governorate to seven different insecticides. Results showed a good robustness and repeatability of the method. Similar conclusions were reported by (Reyes *et al*., 2012 and Roditakis *et al*., 2013), confirming that the method is easy to perform, robust and repeatable.

A susceptible strain was not a vailable and the results did not allow identifying a general standard susceptible strain from the ones tested. So, the laboratory strain was used as reference. It was collected from different infested tomato fields of El- Salhia region (SSR) and was maintained in continuous mass rearing under the laboratory conditions for 19 generations without any insecticides selection pressure. We assumed that this long time was enough to lose any probable resistance mechanism (metabolic resistance and AChE mutation). However, the time needed to accomplish that will vary according to the implicated mechanisms. These results agrees with those obtained by Reyes *et al*. (2012) who used a reference strain of *T. absoluta* collected from Maule region from tomato crops and maintained in continuous mass rearing in the laboratory for 15 generations without any selection pressure. They found the mortality of reference strain was the highest than expected (91.7%), and the lowest mixed function oxidases (MFO) and general esterases (EST) activities. These characteristics confirm the convenience of use it as reference.

T. absoluta has been controlled mainly with chemicals belonging to organophosphates and synthetic pyrethroids classes, but the intensive use of these insecticides led to the development of resistance (Salazar and Ararya, 1997). Also, significant resistance of *T. absoluta* to deltamethrin, abamectin, cartap, methamidophos and pyrethrin used against this insect pest was additionally reported by (Lietti *et al*., 2005). Gerson *et al*. (2011) surveyed resistance levels in *T. absoluta* populations in Brazil to the main insecticides currently used and recommended. They found that this insect had a high resistance levels against permethrin, diflubenzuron, teflubezuron, triflumuron and *B. thuringiensis*, moderate levels of resistance to indoxacarb and no resistance levels against spinosad. Haddi *et al*. (2012) who used a leaf dip methodology to evaluate the susceptibility of the five strains of *T. absoluta* from three different countries i.e., Spain, Portugal and Italy to six different insecticides belonging to four different classes namely lambda-cyhalothrin, tau fluvalinate, chlorpyrifos, imidaclopride, thiaclopride and rynaxpyr. They found that the comparison between the most susceptible strain and other strains showed that differences were ranging between 4 to 17 fold for lambda-cyhalothrin, 2 to 11 fold for tau fluvalinate, 7 to 30 fold for imidaclopride and less than 5 for chorpyriphos and thiaclopride. Also, Yalcin *et al.* (2015) determined the insecticides resistance of two *T. absoluta* (Aydin and Urla) populations to five insecticides belonging to five different insecticides classes (indoxacarb, spinosad, azadirachtin, chlorantraniliprole and metaflumizone). They found that *T. absoluta* Aydin population had higher resistant values 8.00-, 3.79-, 6.40- and 1.84- fold for indoxacarb, metaflumizone, spinosad and chlorantraniliprole, respectively to all insecticides except azadirachtin compared with the Urla population. Also, they indicated that *T. absoluta* Urla population was the most susceptible in comparison with *T. absoluta* Aydin population to other tested insecticides, except azadirachtin.

On the other hand, Radwan and Taha (2012), in Egypt, evaluated the toxic effect of imidaclopride on both *T. absoluta* 4th instar larvae and adults under controlled laboratory conditions and found that this insecticide was the superior toxicant against this insect.

Biological aspects of both *Tuta absoluta* laboratory reference strain and the most insecticides resistant field population

Statistical analysis of the results shown in Table (2) exhibited that the mean number of eggs/ emerged female from the laboratory reference strain was high significantly varied in comparison with the mean number of eggs/ emerged females of insecticides resistant field population. The highest mean number of eggs/ females was 196.38± 2.76eggs/ female for the tomato leafminer laboratory reference strain. Contrarily, the mean number of eggs/ the females of insecticides resistant field population (SSR) was the lowest 142.50± 1.74 eggs/ female.

Similar results on the mean number of eggs/ *T. absoluta* females were reported by (Pereyra and Sanchez, 2006 and Erdoghan and Babaroglu, 2014) who found that the mean number of eggs/ female of this insect pest on tomato plants was 132.78± 14.16. Also, these results are agree with those obtained by (Fernandez and Montagne, 1990) who recorded the mean fecundity of *T. absoluta* on tomato plants, where it was 241.8± 31.14 eggs per female. The hatchability percentage of eggs deposited by the females of both the two tested strain was insignificant. Hatchabilty percentage was equal 100± 0.00% for the eggs deposited by females of the field and laboratory strains. The obtained results indicated that there was insignificant differences between incubation periods of the eggs deposited by females of the insecticides resistant field population and laboratory reference strain. Eggs incubation periods were equal 4.00± 0.00 days deposited by both females of the two tested strains. These findings are accordance to those obtained by (Erdoghan and Babaroglu, 2014 and Rostami *et al*., 2016) who found that the eggs incubation period of *T. absoluta* on unknown tomato cultivars was 4.10± 0.08. Larval duration was high significantly affected according to *T. absoluta* strains. The larval periods were 12.00± 0.55 and 10.00± 0.53 days for the insecticides resistant field population and laboratory reference strain, respectively. The duration of *T. absoluta* larvae of the insecticides resistant field population was longer than the laboratory reference strain; this may be due to the need of the exposed larvae to longer period to gain its essential requirements of nutrients needed for transformation from instar to another simulataneously with development to the pupal stage. Similar results of the total larval duration of *T. absoluta* on unknown tomato cultivars (10.97± 0.92) was reported by (Erdoghan and Babaroglu, 2014 and Rostami *et al*., 2016).

Table 2. Some biological aspects of *Tuta absoluta* laboratory strain and field strain of El- Salhia field population under laboratory conditions of 26°C and 65% R.H.

Biological Aspect	Strains		calculated T (values)	Probability
	Laboratory	El- Salhia		
Mean no. of laid eggs / female	196.38± 2.76	142.50± 1.74	16.52**	0.000
Incubation period (in day)	4.00± 0.00	4.00± 0.00	$0.00^{N.S.}$	___
Hatchability percentage (%)	100.00± 0.00	100.0± 0.00	$0.00^{N.S.}$	___
Total larval period (in day)	10.00± 0.53	12.00± 0.55	3.74**	0.019
Pupation percentage (%)	76.55± 5.86	99.04± 0.37	3.83**	0.002
Pupal duration (in day)	6.00± 0.00	6.00± 0.00	$0.00^{N.S.}$	___
Emergence percentage (%)	96.61± 0.77	95.79± 1.02	$0.644^{N.S.}$	0.530
Sex ratio (as female)	49.40± 1.15	48.34± 1.51	$0.558^{N.S.}$	0.586
Pre- oviposition period (in day)	2.00± 0.00	2.00± 0.00	$0.00^{N.S.}$	___
Oviposition period (in day)	4.00± 0.00	4.00± 0.00	$0.00^{N.S.}$	___
Post-oviposition period (in day)	2.00± 0.00	2.00± 0.00	$0.00^{N.S.}$	___
Complete developmental period (in day)	20.00± 0.53	22.00± 1.07	$1.673^{N.S.}$	0.116
Mean generation period (in day)	28.00± 0.68	30.00± 0.94	$1.717^{N.S.}$	0.108

-$T_{0.05}$= 2.145; $T_{0.01}$; N.S.= Non- significant; ** highly significant

Also, these results agree with those reported by (Wang *et al*., 1999) who showed that the larval and pupal durations of *Heliothis armigera*, resistant and susceptible strains were lengthened as a result of treatment with fenvalerate. Respecting pupal durations of both resulting from larvae resistant to certain currently field used and recommended insecticides and laboratory reference strain (Table, 2), statistical analysis of results showed insignificant differences in the two tested strains. The mean duration of pupal stage were 6.00± 0.00 and 6.00± 0.00 days for both strains. From the obtained results, it was obvious that the highest adult emergence percentage was 96.61± 0.77% from the laboratory reference strain, whereas the lowest mean percentage of adult emergence was 95.79± 1.02% from the insecticides resistant field population. Statistically analysis of the results using T- test given in Table (2) revealed that the emerged adults sex ratio (as % emerged females) from both field and laboratory strain was insignificant. Resistance to some currently used and recommended insecticides (chlorpyrifos, spinosad and λ-cyhalothrin) was insignificant effect on the lepidopteran complete developmental period in comparison with the laboratory reference strain. The life cycle of *T. absoluta* have been determined to complete in 29- 38 days under different environmental conditions (EPPO, 2005). These results are in harmony with those obtained by Barrientos *et al.* (1998) who found that the mean complete developmental period of *T. absoluta* was 23.8 days at 27.1 °C. Respecting the mean generation time during the first generation (Table, 2), statistical analysis of results showed insignificant differences between the resistant field population to the above- mentioned insecticides and laboratory reference strain. From the obtained results, it can be concluded that the shortest mean generation time was 28.00± 0.68 days for the laboratory reference strain, whereas the longest one was 30.00± 0.94 days for the insecticides resistant field population collected from El- Salhia region.

Residues of λ-cyhalothrin in tomato fruits

Residues and their dissipation of λ-cyhalothrin in whole tomato fruits during a period of 15 days are shown in Table (3). Results revealed that the initial deposit of λ-cyhalothrin on tomato fruits was 0.180 mg/kg. A fast degradation of the tested insecticide residues was noticed, one day after spraying with value of 63.33% dissipation. The initial deposit was faster decreased during the experimental period to reach 0.002 mg/kg after 7 days of λ-cyhalothrin spraying recorded 98.89% reduction in fruits, while no residues of the tested synthetic pyrethroid were detected on the 9^{th}, 11^{th}, 13^{th} and 15^{th} days of spraying. It could be noticed that 0.013 mg/kg of λ-cyhalothrin was detected on whole tomato fruits after 3 days of λ-cyhalothrin application. This indicated that only 3 days were enough time to reduce the residues below the maximum residue limits (MRLs) (0.01mg/kg) on tomato according to EU pesticides database- European Commission. Therefore, tomato fruits could be marketed with apparent safely for human consumption.

These findings are accordance to Kelegeri *et al.* (2017), who indicated that the initial deposit of λ-cyhalothrin in open field tomato fruits was 0.13 mg/ kg after 2 hours of spraying, which decomposed to below determination level (BDL) of 0.05 mg/ kg by 5^{th} day after spraying with the tested insecticide. Also, they showed that the dissipation pattern of lambda- cyhalothrin residues has decreased from first day to 3^{rd} day and residues dissipated by 38.46 and 53.84% at 1 and 3 days, respectively. Whereas, (Jayakrishnan *et al*., 2005; Chauhan *et al*., 2011 and

Gupta *et al*., 2015), who reported that the half- life value of lambda- cyhalothrin was 3.06 days. Elbashir *et al* (2013) reported that the residue values of lambda- cyhalothrin in tomato fruits were detected on first day after application with concentrations of 27.355, 3.047 and 1.103 mg/kg for fenpropathin, λ-cyhalothrin and deltamethrin, respectively. Because the time elapsed after spraying, these amounts continuously decreased to reach 0.708, 0.004 mg/kg and undetectable amounts after 30 days of spraying, respectively. The pesticides reached level lower than MRL after 27 days (fenpropathin), 18 days (λ-cyhalothrin) and 3 days (deltamethrin). Lofty *et al* (2013) reported that λ-cyhalothrin initial deposits in zucchini (0.14 mg/kg) faster degradation to reach 0.005 mg/kg after 8 days of application at the recommended rate of 20 ml /100 L water from the formulation lambda super fog 5% E.C. The same author indicated that $t_{1/2}$ time and the pre harvest interval were relatively 4 days and 5 days, respectively. Romeh and Hendawi (2014) found that $t_{1/2}$ value of fenpropathin in squash fruits was 1.78 days. Fenpropathin residues levels in squash fruits below MRL (1.0 mg/kg) were determined after 3 days of λ-cyhalothrin application and no residues were detected on the 10th day. Kadam *et al* (2015) determined that the initial deposits of λ-cyhalothrin in fruits of pomegranate were 0.120 and 0.170 mg/kg after λ-cyhalothrin application with 5.25 and 10.50 g a.i. /Fed., respectively. These amounts were decomposed to reach 0.018 mg/kg and 0.032 mg/kg after 7 days of application, respectively.

Table 3. Residues of lambda- cyhalothrin detected in tomato fruits at different intervals.

Days after treatment	Fruits	
	Residues (mg/ kg)	Loss %
2 hrs	0.180	___
1day	0.066	63.33
3days	0.013	92.78
5 days	0.005	97.22
7 days	0.002	98.89
9 days	UND	100
11 days	UND	100
13 days	UND	100
15 days	UND	100
K	0.6900	
$t_{1/2}$	1.004	

K= Degradation rate, $t_{1/2}$= Half- life and UND= undetectable amounts

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تقصي المقاومة للمبيدات الحشرية في تعادين حقليين لحشرة صانعة أنفاق أوراق الطماطم *Tuta absoluta* (Meyrick) ومتبقيات مبيد اللمبدا- سيهالوثرين في ثمار الطماطم

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أصبحت مقاومة حشرة صانعة أنفاق أوراق الطماطم للمبيدات الحشرية من المشاكل الخطيرة في العديد من مناطق إنتاج الطماطم في مصر.تهدف هذه الدراسة إلى تقصي مستويات المقاومة لبعض المبيدات الحشرية المستخدمة في الوقت الحالي (اللمبدا- سيهالوثرين، الكلوربيرفوس و الايميداكلوبريد) والموصى بها (الكلورانترانيليبرول، الايمامكتين بنزوات، الاسبينوساد و الاندوكساكارب) ضد حشرة *T. absoluta* والتي تم تجميعها من منطقتين مختلفتين، الصالحية (منطقة سامي سعد) ومنطقة أبوكبير في محافظة الشرقية. دراسة بعض النواحي البيولوجية المرتبطة بمقاومة المبيدات الحشرية المستخدمة في السلالة الحقلية (منطقة سامي سعد) والسلالة المعملية المرجعية. أيضاً، تقدير متبقيات مبيد اللمبدا- سيهالوثرين في ثمار الطماطم. أوضحت النتائج وجود اختلافات معنوية في مستويات التحمل و/أو المقاومة للمبيدات الحشرية المستخدمة بين مجتمعين حقليين من هذه الآفة الحشرية. أيضاً، أوضحت النتائج أن المقاومة لبعض المبيدات (الكلوربيرفوس، الاسبينوساد و اللمبدا- سيهالوثرين) أدت الى تأثيرات غير مرغوب فيها في بعض النواحي البيولوجية لتعداد الصالحية المقاوم مقارنة بالسلالة المرجعية المعملية (عدد البيض الموضوع/ أنثى ومدة الطور اليرقي). قُدرمتبقي مبيد اللمبدا- سيهالوثرين ومعدل اختفاءه في ثمار الطماطم على فترات مختلفة بعد ساعتين، يوم، 3، 5، 7، 9، 11، 13 و 15 يوم. أظهرت النتائج أن نسبة الفقد للمتبقي الأولي في ثمار الطماطم كانت 0,180 ملجم/ كجم وفترة نصف العمر ($t_{1/2}$) للمبيد في ثمار الطماطم كانت تقريباً يوم. وأشارت النتائج المتحصل عليها أن ثمار الطماطم يمكن استهلاكها بامان بعد 3 أيام من المعاملة بمبيد اللمبدا- سيهالوثرين.